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SOLAR ACTIVITY AND THE GREAT RED SPOT OF JUPITER

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ABSTRACT

A search for possible Solar Jovian Relationship has been made using the darkness parameter of the Great Red Spot of Jupiter, over the period 1891 - 1967. In common with other solar terrestrial phenomena, on the average, we observe a characteristic double maxima in the changes in the parameter during the eleven year solar cycle.

I. INTRODUCTION

The interplanetary medium and the geophysical environment including the upper atmosphere and magnetosphere, are profoundly influenced by solar activity. Investigations during the past decade have provided interesting details about the relationships amongst various geophysical phenomena and thus enhanced our understanding of the interaction between solar wind and the geomagnetic field. The studies of the modulation of cosmic rays indicate that the solar influence extends over a very large region. The present estimates of the boundary of the region of cosmic ray modulation extend from 5 AU to 50 AU (Dessler (1967), Simpson and Wang (1967), Hundhausen (1968)).

Jupiter is at a distance of 5 AU, and is a planet with a deep atmosphere. It has a magnetic field and there is evidence of an associated radiation belt (Michaux (1967)). A search for possible Solar Jovian relationships is of interest. Two Jovian phenomena

appeal to us as suitable for investigation; the Decametric Emission and the Great Red Spot. Smith and Carr(1964) from a study over the period 1957 - 1961, have suggested a possible inverse correlation between solar activity and the average probability of emission of decametric radiation. In this article, we discuss the possible relationship between the darkness of the great red spot of Jupiter and solar activity.

II. THE GREAT RED SPOT OF JUPITER

The Jovian red spot has been under observation since 1891. A visual estimate of the darkness of the red spot is available for each year. This is indicated by numbers, which are assigned by observers at each apparition. Table I gives the adopted scale, as given by Peek (1958) who has collated the observations for the period 1891 - 1947. For the years 1948 - 1967, E. J. Reese has used Peek's criteria and determined the values of the darkness parameter, as reported by Solberg and Chapman (1969).

It should be realized that there is a certain amount of arbitrariness in the assignment of numbers by various observers. Hence, one should bear in mind that any analysis is subject to the limitations of the lack of precision of this parameter. The use of individual values for each year for intercomparison over any single solar cycle, may be open to question, in view of the qualitative nature of the parameter, but we believe it is appropriate to study the average behavior over a number of solar cycles.

TABLE I

Scale adopted by Peek (1958) for the darkness parameter of the Jovian Red Spot:

Description	Number
Invisible	0
Very faint but visible	1
Very difficult early in the apparition; later quite plain and distinct	2
Fairly well defined	3
A well defined object	4
An easy object	5
Easy and fairly conspicuous	6
Very dark and conspicuous	8

It is pertinent to point out that there is likely to be considerable difference amongst various observers in assigning the numbers at either end of the scale.

III. SOLAR ACTIVITY AND THE DARKNESS PARAMETER OF THE JOVIAN RED SPOT

From a visual comparison of the time series of the yearly values of the Jovian red spot parameter, and of R, the Zurich relative sunspot number, over the period 1891 - 1947, Graf et al (1968) have concluded that "there is a pronounced correlation between the cyclic maxima and minima of the two curves". It is quite clear from their diagram that such an unequivocal generaliza-

tion is untenable. Argyle (1968) has shown that the correlation coefficient between the two variables is only +0.27. Solberg and Chapman (1969) have considered the entire period 1891 - 1967, and obtained a correlation coefficient of +0.16. These authors have further pointed out that the correlation coefficient is not significant at the five percent confidence level.

IV. PRESENT ANALYSIS

We have used the entire data and adopted the superposition method similar to the Chree method (Chree (1913), Chree and Stagg (1928)) to investigate the relationship between R, the Zurich relative sunspot and the Jovian parameter over an "average solar cycle". The "Zero epoch" is centered on the years of solar maxima, as selected from the annual means of R. The values for the four years preceeding and for the seven years following the years of maxima are used for superposition. The analysis thus corresponds to seven solar cycles, with the years of maxima being 1893, 1905, 1917, 1937, 1947, and 1957. The same years are used as "Zero epoch" years for the Chree analysis of the Jovian parameter. The results of the analyses are shown in Figure 1. The lack of a significant linear correlation between the two parameters is also obvious from this diagram.

V. DISCUSSION AND INTERPRETATION OF THE RESULTS

The curve for the Jovian index, with two maxima and a rather

pronounced minimum in between, coinciding with high solar activity as seen from the sunspot number, is quite impressive. The presence of double maxima in the 11-year cycle of solar activity has been pointed out by Gnevyshev (1963, 1967), who indicates that events in the photosphere, the chromosphere and the corona, and radio and particle emissions from the sun, exhibit this feature. Further, the double maxima have also been observed in Polar Cap Absorption events (Gnevyshev (1967)); in cosmic ray intensity and in geomagnetic activity (Balasubrahmanyan (1968), Venkatesan (1958), and Balasubrahmanyan and Venkatesan (1969)). Some of these are shown in Figure 2 for solar cycles 18 and 19. It is relevent to point out that the separation of the maxima could be different for different cycles, as also how pronounced the minimum is for different phenomena. In Figure 3, we have plotted the Jovian parameter for the two solar cycles covering the epoch 1922 - 1945, where the double maxima are clearly seen. It is possible that this behavior becomes hard to detect if the two maxima in solar activity overlap or if there are limitations in the Jupiter observations.

Thus, the similarity between the long term changes in the darkness parameter of the Jovian red spot and the long term changes in the phenomena on the sun and in phenomena involving solar terrestrial relationships is striking. This suggests a common genesis and indicates the extent of solar control. The mechanism by which solar energy is transmitted to the Jovian atmosphere as well as the exact cause of the change in the

intensity of the Jovian red spot need investigation.

The fact that a consistent feature, in common with various other phenomena, is revealed even by the semi-quantitative measure of the Jovian red spot, enhances the value of the useful data available for the past 80 years. This further points out the necessity of making quantitative measurements using presently available sophisticated techniques. Such quantitative measurements would also be extremely useful during solar proton events, subject to apparition and observing conditions. If the above analysis is correct, we should expect an enhancement of the darkness of the great red spot, if the solar flare events take place in a favorable solar longitude. Such studies would lead to a better understanding of Solar Jovian relationships and possibly of the extent of the heliospheric boundary.

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CAPTION FOR FIGURES

Figure 1. Chree type analysis; average over seven solar rotations. "Zero Epoch" years correspond to years of maximum solar activity as chosen from annual means of sunspot numbers. Jupiter index refers to the darkness parameter of the Great Red Spot of Jupiter (Peek (1958)).

Figure 2. Examples of phenomena exhibiting double maxima during the Solar Cycles 18 and 19; Cosmic Ray Intensity refers to annual mean values at Cheltenham (Fredericksburg), in units of 0.1% from fiducial value; Geomagnetic Disburbance refers to the sum of daily values of Kp, the planetary geomagnetic index, for 60 most disturbed days for the year (five values for each month); Coronal 5303 Å refers to the intensity of the coronal line at 5303 Å averaged around the limb; PCA events refer to the annual number of Polar Cap Absorption events. The last two curves have been taken from Gnevyshev (1967).

Figure 3. R represents the mean annual Zurich Sunspot number for the epoch 1922 - 1945. Also shown for the same period are the values of the Jovian red spot darkness parameter for each year. No data was available for the years 1930 and 1942.

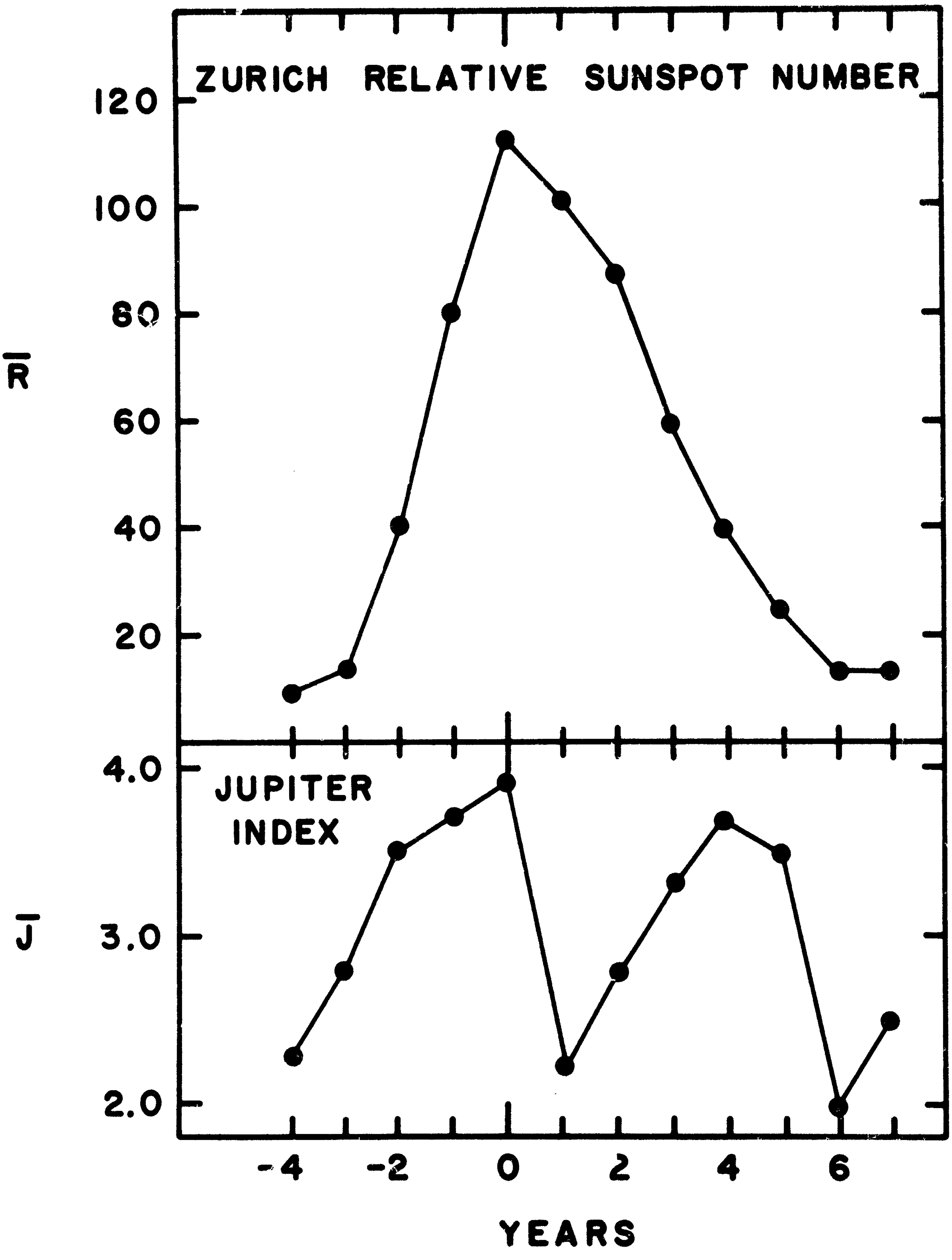
ZURICH RELATIVE SUNSPOT NUMBER
120
100
80
60
40
20
R̄
4.0
3.0
2.0
J̄
JUPITER
INDEX
-4
-2
0
2
4
6
YEARS

FIGURE I

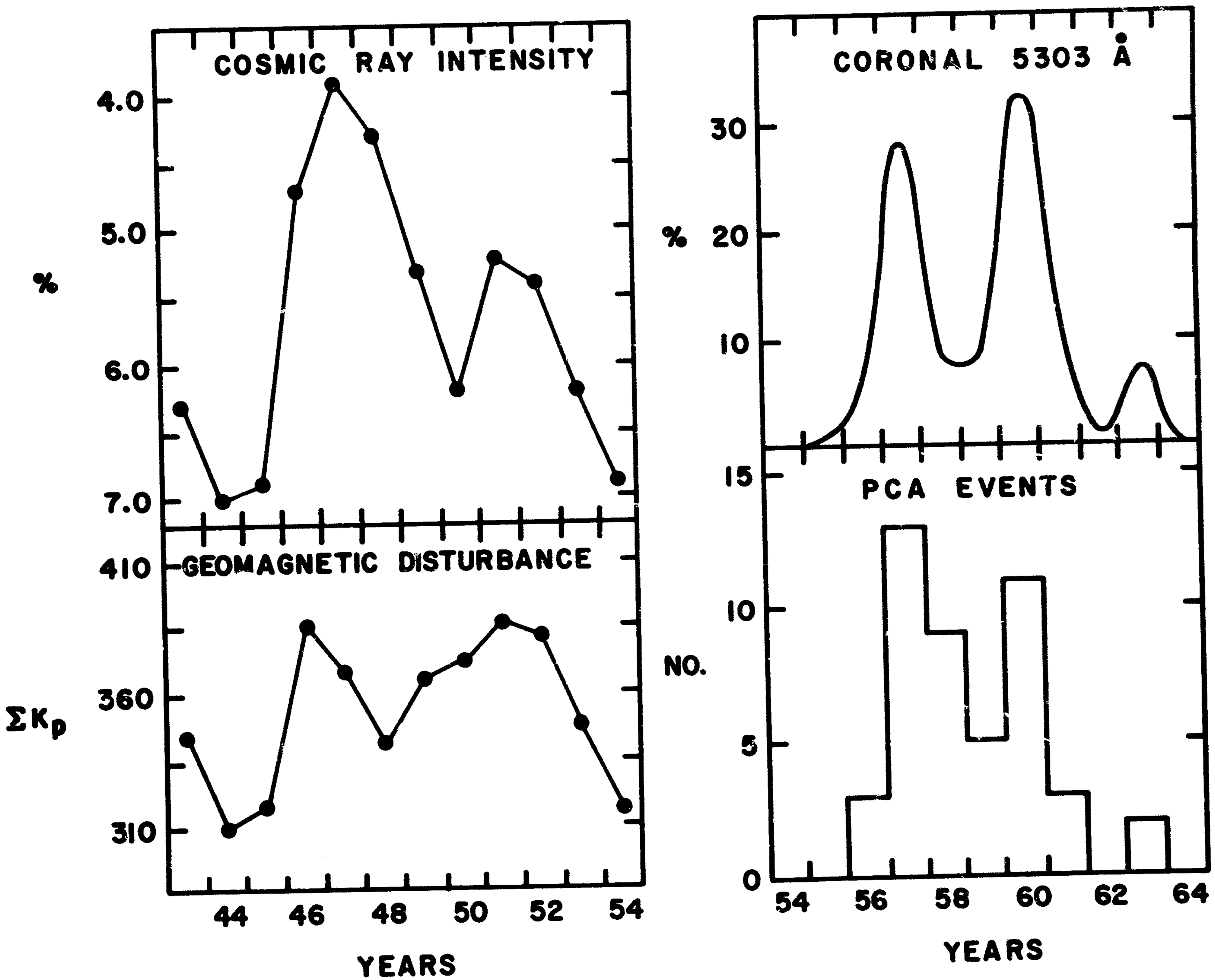
COSMIC RAY INTENSITY
%
4.0
5.0
6.0
7.0
GEOMAGNETIC DISTURBANCE
ΣKp
410
360
310
44
46
48
50
52
54
YEARS
CORONAL 5303 Å
%
30
20
10
PCA EVENTS
NO.
15
10
5
0
54
56
58
60
62
64
YEARS

FIGURE 2

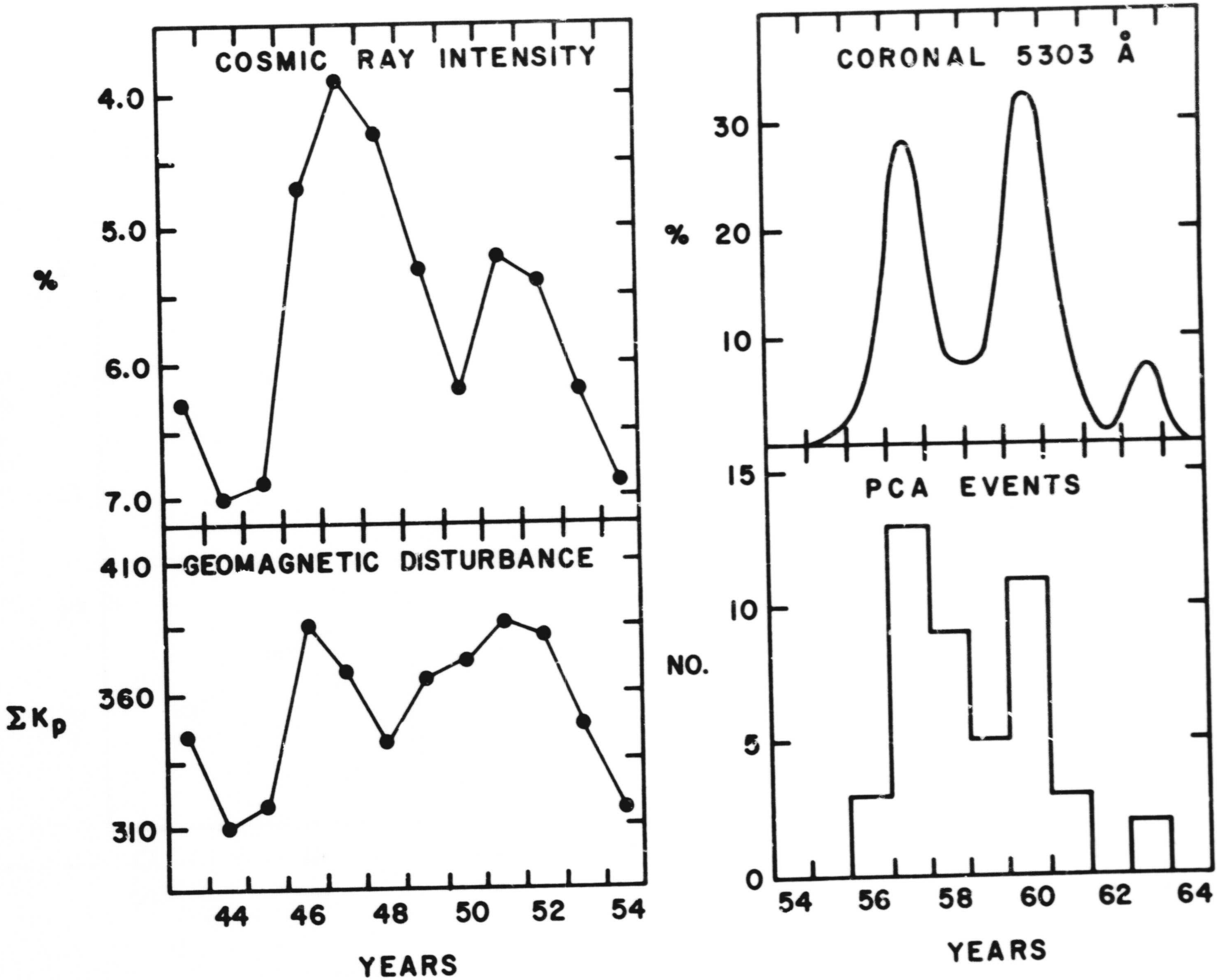
COSMIC RAY INTENSITY
%
4.0
5.0
6.0
7.0
GEOMAGNETIC DISTURBANCE
ΣKp
410
360
310
44
46
48
50
52
54
YEARS
CORONAL 5303 Å
%
30
20
10
PCA EVENTS
NO.
15
10
5
0
54
56
58
60
62
64
YEARS

FIGURE 2

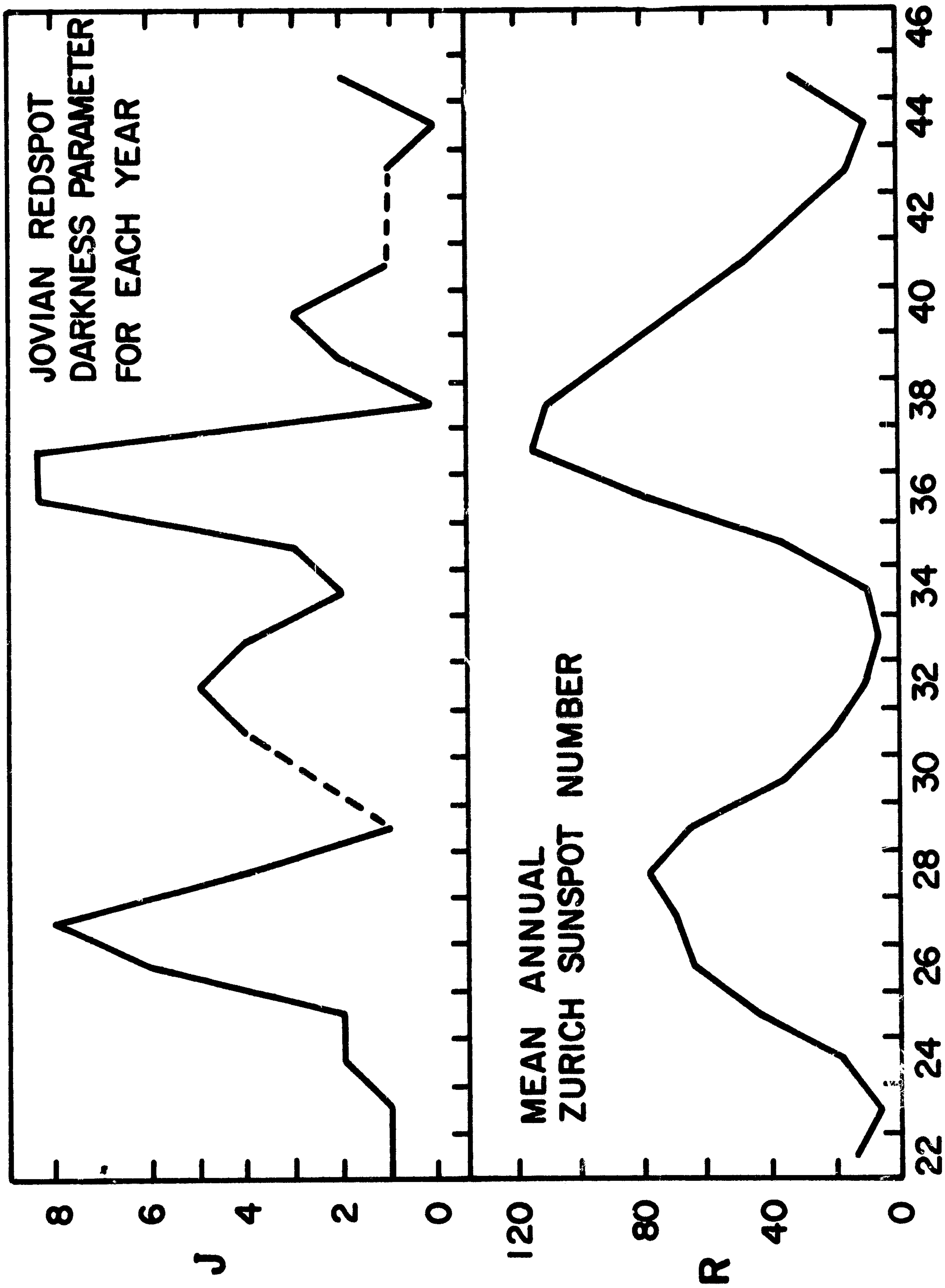
JOVIAN REDSPOT
DARKNESS PARAMETER
FOR EACH YEAR
MEAN ANNUAL
ZURICH SUNSPOT NUMBER
J
R
8
6
4
2
0
120
80
40
0
22
24
26
28
30
32
34
36
38
40
42
44
46
YEARS (1900'S)

FIGURE 3